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[54] **APPARATUS FOR PRODUCING GRANULES FROM MOLTEN METALLURGICAL SLAGS**

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Related U.S. Application Data

[60] Division of Ser. No. 2,099, Jan. 9, 1979, abandoned, which is a continuation-in-part of Ser. No. 828,856, Aug. 29, 1977, abandoned.

[51] **Int. Cl.**[3] **B29B 1/54**
[52] **U.S. Cl.** **425/8**
[58] **Field of Search** 425/8

[56] **References Cited**

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[57] **ABSTRACT**

An apparatus for manufacturing granules from slags produced in metallurgical furnaces such as blast furnaces, converter furnaces, electric furnaces, reverberatory furnaces comprising means for accelerating a stream of molten slag from a container to a velocity of at least two meters per second, and directing the stream onto a target surface from which it rebounds in the form of an inverted cone of droplets which are projected through the air to cool and to solidify them into granules.

4 Claims, 4 Drawing Figures

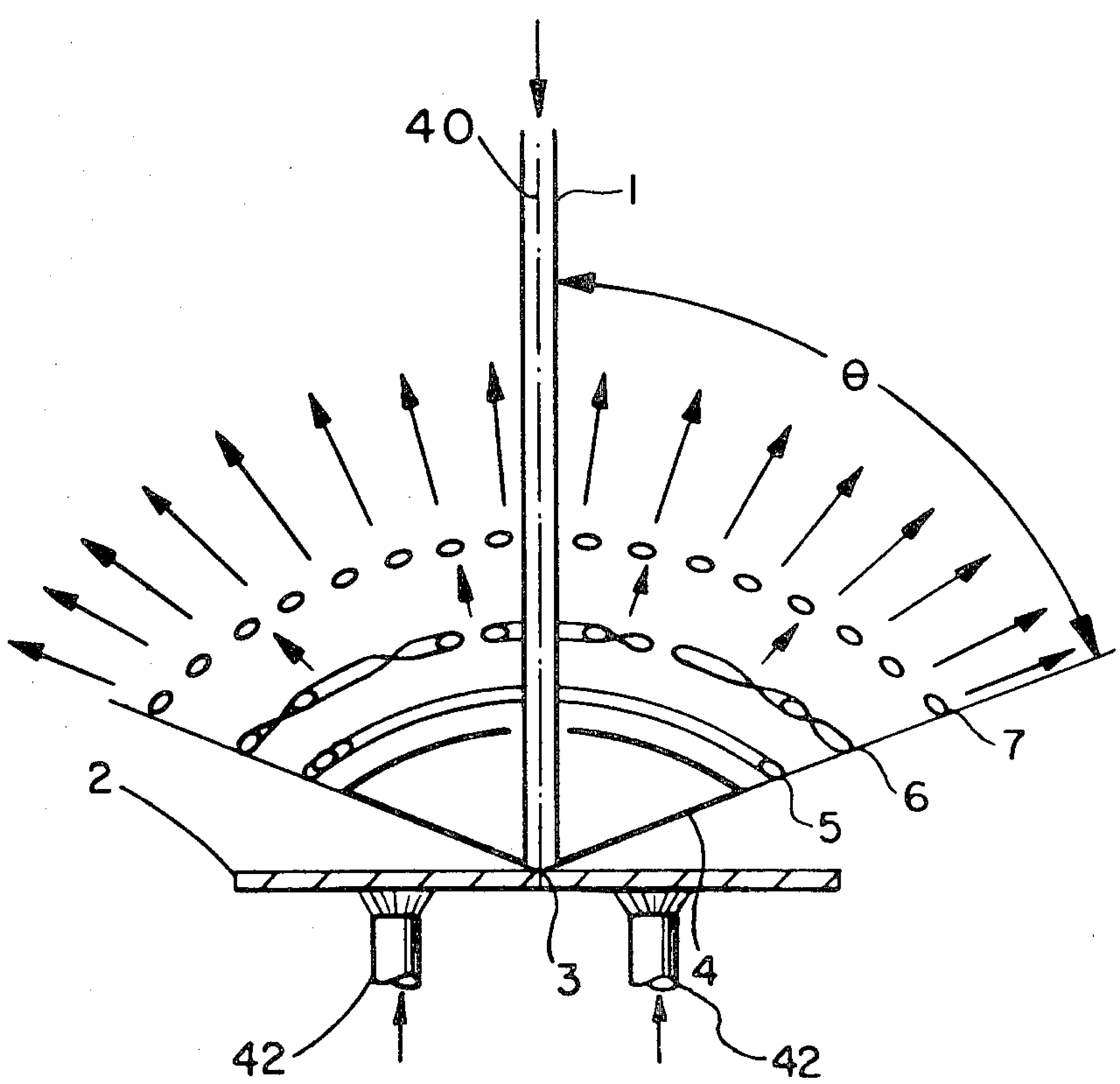


FIG. 1.

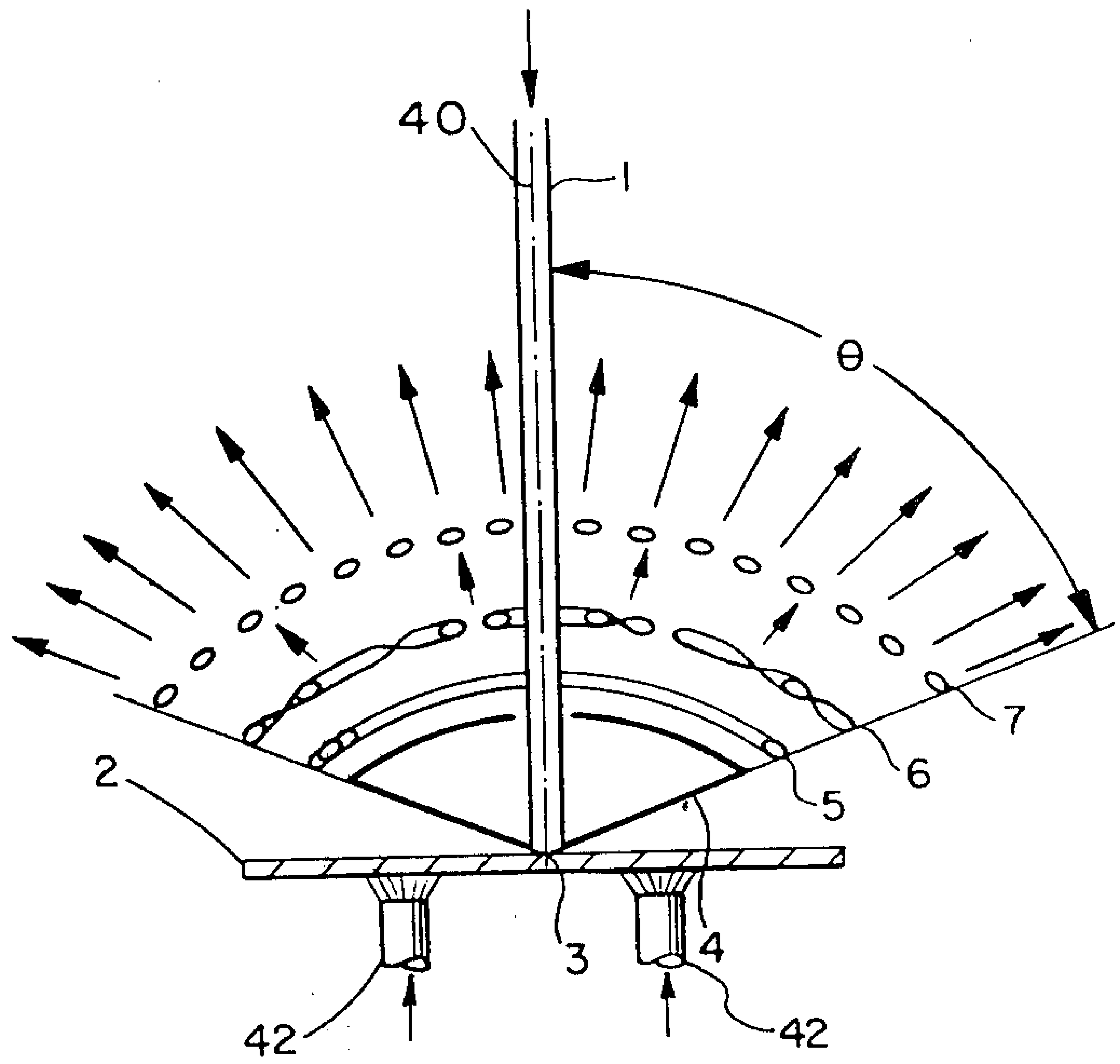


FIG. 2.

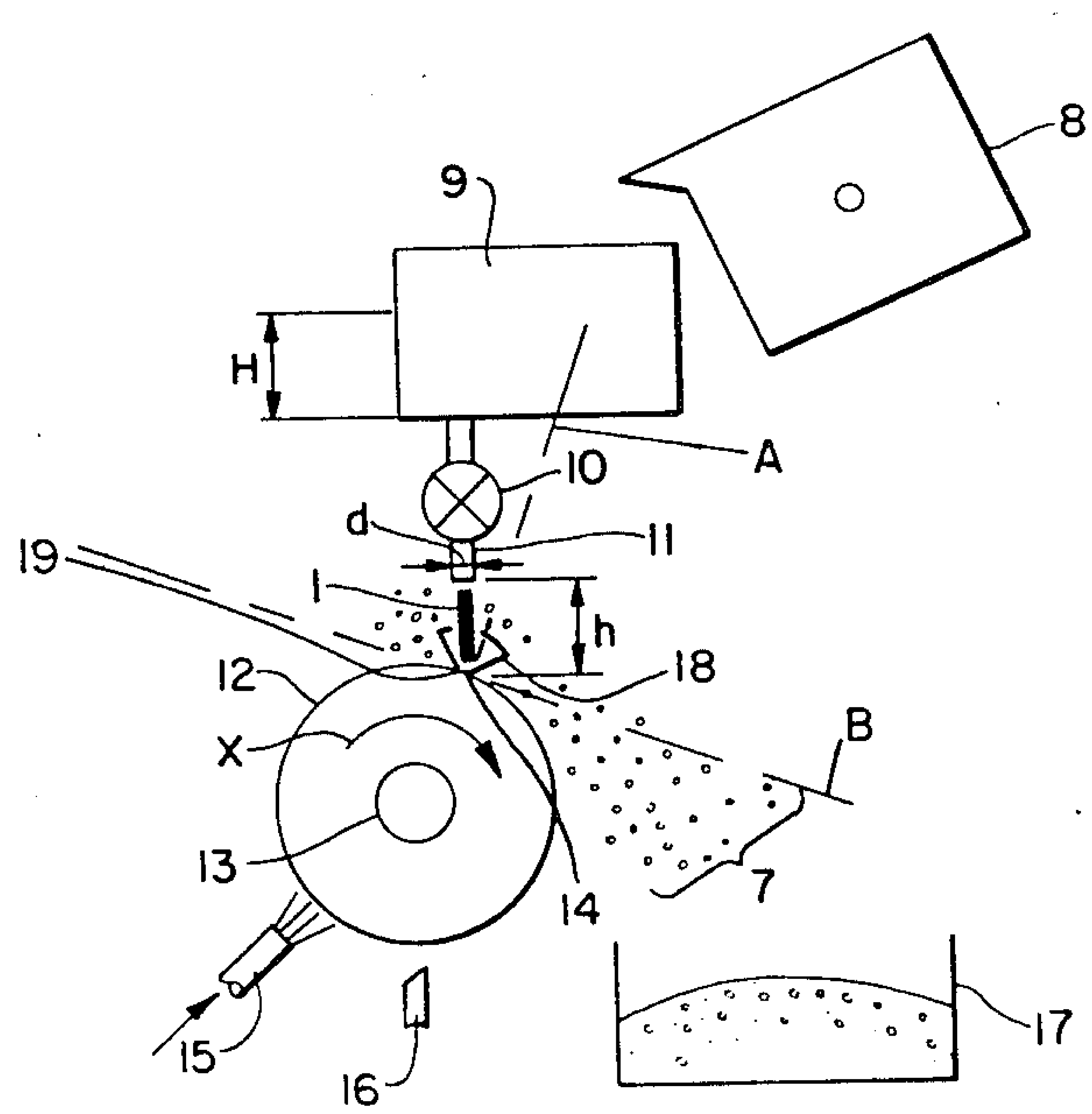


FIG. 3.

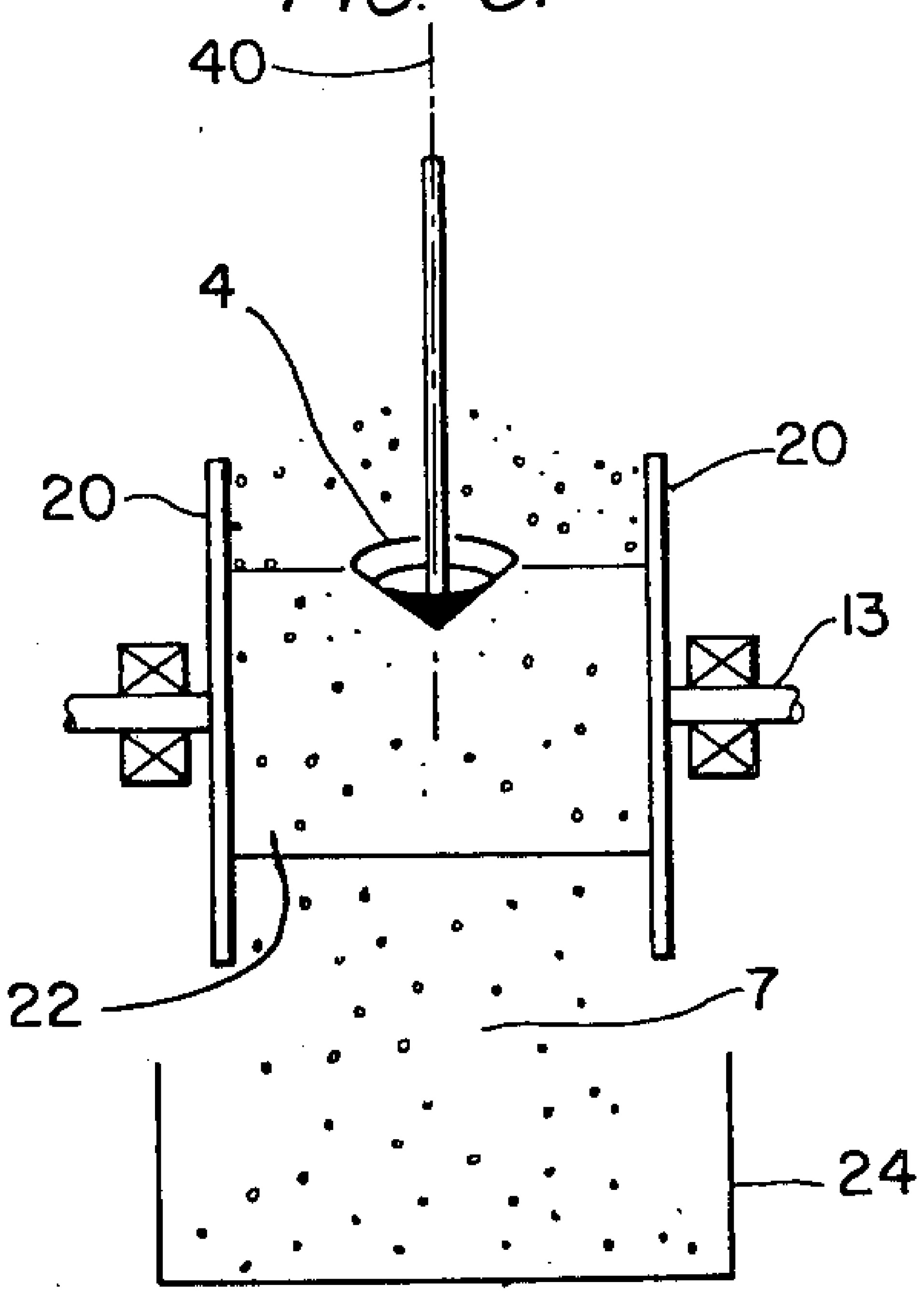
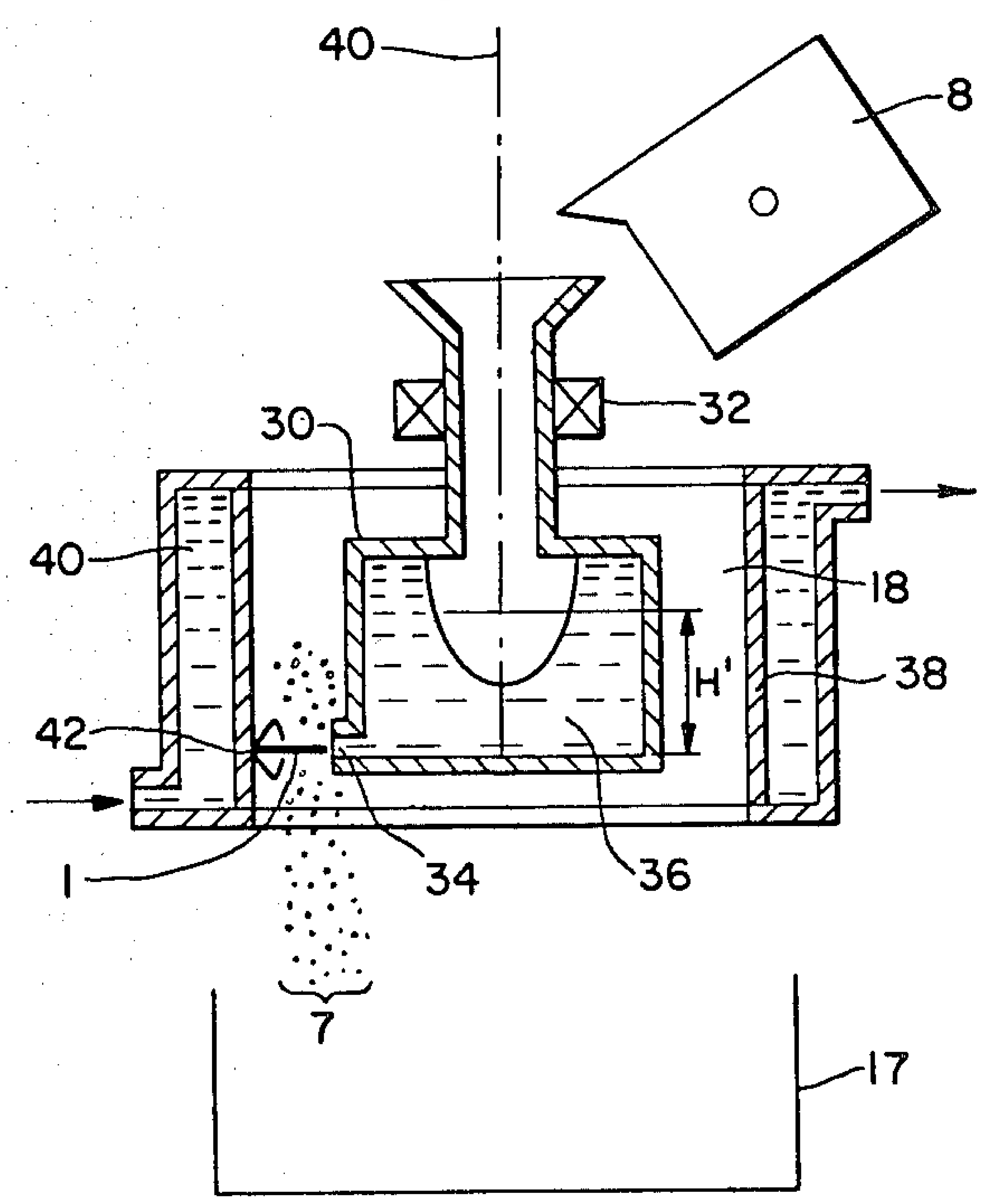


FIG. 4.



APPARATUS FOR PRODUCING GRANULES FROM MOLTEN METALLURGICAL SLAGS

This application is a division of application Ser. No. 002,099 filed Jan. 9, 1979 which itself is a continuation-in-part of application Ser. No. 828,856 filed Aug. 29, 1977, both now abandoned.

DETAILED DESCRIPTION OF THE INVENTION

This invention provides apparatus for producing granules from slags produced in metallurgical furnaces such as blast furnaces, converter furnaces, electric furnaces, reverberatory furnaces, and the like.

Because such metallurgical slags are produced in great quantities there is a demand for their disposition in a nonpolluting manner, preferably by converting them into useful substances such as an aggregate used in concrete making. For this purpose, slag granules having a mean diameter of 2 to 4 mm, a maximum diameter of less than 15 mm and preferably less than 10 mm, and of a uniform size distribution, a strength equivalent to river sands, and spherical shape are particularly desired.

Methods and apparatus are known for making such granules solidified by a water spray, and also by the hydrogranulation process, in which molten slag is comminuted with a water jet. However, no known method or apparatus has been successful in producing granules of the size, size distribution and strength mentioned above. Granules having the desired properties can be produced by the apparatus of this invention.

The present invention will become more apparent from the following description of preferred embodiments thereof taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic drawing of the inverted cone film of molten slag rebounding from the target surface;

FIG. 2 illustrates one embodiment of the invention; of the invention;

FIG. 3 is a front view of a modified form of the apparatus from FIG. 2; and

FIG. 4 illustrates another embodiment of the invention.

FIG. 1 represents observations of the rebounding inverted cone of slag made by high speed photography. Slag stream **1** impinges on target surface **2** at point **3**, from which an inverted conical film **4** of slag of a half apex angle θ is formed with the central axis **40** of the slag stream. Slag film cone **4** degenerates from its outer circular edge into a series of expanding slag rings **5** and **6** which, in turn, are broken into numerous spherical droplets **7**. Moving outwardly in all directions along the conical shape, the droplets are progressively cooled and solidified by the surrounding air to form granules.

The velocity with which the molten slag stream impinges upon the target must be at least 2 m/sec, and the target surface **2** must be non-wetting with respect to the molten slag. This latter requirement is achieved by forming target surface **2** of hard, heat resisting and heat conducting material such as iron, mild steel, stainless steel, copper, or copper alloy. The target surface may be reinforced by a hard facing through a surface treatment such as aluminizing, parkerizing, chromium plating, carburizing, nitriding, or buttering of superalloy. In other cases, ceramics and graphite, though not particularly heat conductive, were found also satisfactory. In any case, the surface should be finished to a high degree

of smoothness such as that obtained by fine grinding or cold rolling, and should be kept cooled. Cooling water applied to the side of the target opposite the impingement side is generally sufficient. Alternatively, the target surface **2** can be made non-wetting by coating it with a non-wetting film forming substance such as water, aluminum powder paint, oil, lime milk, or graphite powder paint. A very thin film, for example one obtained when a steel plate is moistened by spray of fine water mist, is generally sufficient. The following experiments demonstrate these points.

EXAMPLE 1

In FIG. **1** target surface **2** is a horizontal copper plate of 10 mm thickness, cooled from below by water sprays **42**. Slag stream **1** may be a blast furnace slag, and LD converter slag, or a copper converter slag (the return slag) directed normally to target surface **2**. The non-wetting substances tested were: either aluminum powder paint for blast furnace slag, lime milk, or oil for converter slag, and either none or water for return slag. Self-granulation was achieved in all cases with an impinging velocity of at least 2 m/sec, though the formed granules tended to be coarse and irregularly shaped near this lower limit.

EXAMPLE 2

In FIG. **2**, **8** is the source of molten slag supplying tundish **9** in which a mass of molten slag of depth H is maintained, **10** is a valve, **11** a nozzle having diameter d, **12** is a rotating drum target which is driven by a mechanism (not shown) through drive shaft **13** in the direction of arrow X. Cooling water is supplied through drive shaft **13**. Rotating the drum up to 100 rpm causes the impingement point **14** to be continually cooled and cleaned, while preventing localized overheating of the target surface. However, if other factors require it, speeds of several hundred rpm may be used equally well. In short, the rotational speed of the drum is not critical. Further, there may be provided a spray nozzle **15** to spray the non-wetting liquid on the rotating drum. Scraper **16** removes bits of slag which may adhere to the drum. Both nozzle spray and scraper **16** are used to prepare or restore the target surface condition. Receptor **17**, which collects the granules may be a vessel or a belt conveyor positioned beneath the drum.

The slag stream is accelerated through free fall to velocity u, which is predetermined in accordance with the granule size and size distribution desired. The magnitude of velocity u is controlled by h, the distance between the tip of the cone **19** and the impingement point **14**, or by H, or by h and H combined, as well as the temperature of the slag, and d, which determines the flow rate m together with u. The slag droplets are projected several meters through the cooling air, initially causing a solid outer skin to be formed before the droplets fall into receptor **17** as granules.

Conditions in this example were blast furnace slag at a temperature of 1,400° C., H=30 cm, h=1.5 m, d=15 mm, m=50 kg/min, and u=5.9 m/sec (calculated). Drum **12** was a 60 cm outer diameter cylinder, made of a cold rolled sheet steel (0.9 mm thick), rotated between 20 to 200 rpm and internally water cooled. Neither spray nozzle **15** nor scraper **16** was used. The product granules had the properties shown in the Table. No effects were observed by changing the speed of rotation of the drum.

When impinging point **14** is advanced approximately 10° to 20° in the direction of rotation of the target, slag granules **7** are projected at an angle in the direction of rotation. This provides a more efficient collection of granules at receptor **17** because slag cone **18** is symmetrical around A, a line normal to plane B, a line tangent to the drum surface at impingement point **14**.

EXAMPLE 3

FIG. **3** shows an improved design of the rotating drum type of target in which flanges **20** at each end of drum **22** serve to deflect the flight of laterally projected droplets in the direction of rotation of the target, thus improving the collection of the granules in receptor **24**.

The conditions and apparatus were the same as in Example 2, except d was 30 mm, m was 200 kg/min. Water was sprayed onto the vertical flanges **20** as well as onto drum **22**. The results are shown in the Table.

EXAMPLE 4

In FIG. **4**, a tundish **30** is rotated about a vertical axis by a mechanism **32**, and is provided with a laterally directed nozzle **34**. A mass of molten slag **36** of an effective depth H′ is maintained in tundish **30**. The target is a stationary cylinder **38** which is concentric with the tundish and is externally cooled by a water jacket **40**. The inner concave surface of cylinder **38** provides impingement point **42** from slag stream **1**. Acceleration of the slag stream **1** to the impingement velocity u is created by centrifugal force upon slag stream **1** by the rotation of tundish **30**.

In this example a blast furnace slag was heated to 1,400° C., H′=30 cm (estimated), d=15 mm, effective inner radius of 30=15.5 cm, m=100 kg/min, N=400 rpm, inner radius of cylinder **38**=40 cm, u=7.0 m/sec (calculated). The target surface was stainless steel of fine ground finish, and an oil mist was applied to it. The results are shown in the Table.

TABLE

Properties of Slag Granules

Example No.	Mean Dia. (mm)	Max. dia. (mm)	Occurrence of small granules	Distribution	Strength re. river sands
2	3	10	Under 0.5 mm was 1%	Uniform	Same
3	2	9	Under 0.5 mm was 2%	Uniform	Same
4	4	12	Smallest was 1 mm	Richer in large ones	Slightly softer

The invention is based on the phenomenon that molten slags can be granulated into spherical particles when striking and rebounding from a nonwetting hard, smooth cooled surface at an impinging velocity of at least about 2 m/sec. The molten slag stream may be accelerated to the desired velocity under an applied gas pressure. The rotating drum target of Examples 2, 3 and 4 may be equipped with a number of partitioning vertical fins (not shown) to adapt the drum target to a multiple-nozzle multiple-slag stream operation. In the embodiment of FIG. **4**, a plurality of nozzles **34** may be provided instead of the one shown. Cylindrical target **38** may be made to rotate in the direction counter to tundish **30**.

The advantages of this invention are:

(1) it permits manufacture of spherical slag granules with the size and size distribution selectable in a wide range;

(2) it is nonpolluting in that it can be performed in an enclosure to prevent such polluting substances as noxious gases and dusts from escaping into the environmental atmosphere; and

(3) because it converts slags, a substance that is often a mere waste, into a useful substance by means of a simple, rugged, and inexpensive apparatus for a small power expenditure, it is economical, energy saving, and resources saving.

We claim:

1. An apparatus for producing granules from molten metallurgical slag, comprising:

a. a container for the molten slag, and having an outlet for a stream of the slag,

b. a cooled non-wetting target surface having a high degree of smoothness adjacent to and spaced from the outlet for receiving by impingement, a stream of the molten slag from the outlet of the container,

c. means to direct the stream of molten slag from the outlet to impinge upon the target surface at a velocity to cause the stream to rebound therefrom and form an expanding film in the form of an inverted cone with the apex at the point of impingement on the target surface, wherein the cone is formed from degenerating expanding flying rings of the slag from which droplets are subsequently formed and projected along the cone form,

d. means to provide cooling air through which the projected droplets pass to cool and solidify to form the granules, and

e. means to collect the solid granules.

2. The apparatus of claim **1** wherein the target surface is the peripheral surface of a rotating drum.

3. The apparatus of claim **1**, wherein the container is a rotating cylinder having a vertical axis and a lateral aperture from which the molten slag is projected as a stream against the target, wherein the target comprises the inner surface of a cylinder concentrically surrounding the rotating container.

4. The apparatus of claim **1** wherein the target surface comprises plural sides, one side receiving the impinging molten slag, and the opposite side having means for receiving a cooling fluid for cooling the target surface.

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